C3I and Tactical Picture Compilation: Detect, Assess, Allocate, and Respond

Mr. Lawrence H. Luessen

The members of the command team of today's surface combatant—i.e., those responsible for making tactical decisions—are oftentimes faced with an environment that is "data rich," but "information poor." That is, large amounts of sensor data are routinely available, but we lack the ability to process this data into tactically useful information. This is especially true for a naval force conducting operations in the littoral environment of today's surface warfare encounters. This places an increasing amount of strain on the processing and decision-making capabilities of the human components employed throughout the command, control, communications, and intelligence (C3I) process and the forming of a coherent tactical picture (CTP). As the amount and complexity of the sensor data increases, the challenge is to establish a process for automatically assimilating this data into information that can be used by the command team to aid in making better tactical decisions. The resultant available information must then be used to compile and present to the command team a CTP; i.e., a clear, consistent, and intuitively obvious display of all real-world objects (RWOs) of interest to users across the force within an operator-selectable region of interest. Forming a CTP is part of the C3I information management process, whose principal function aboard surface combatants is to determine and provide to the command team the identification (ID) and kinematics of the RWO. This article addresses these issues, employing an author-developed Detect-Assess-Allocate-Respond (DAARE) sequence to describe and discuss the C3I process and the building of a CTP.

Introduction

The need for a clear, consistent, and coherent tactical picture is paramount to a naval force's ability to conduct operations in the littoral environment of today's surface warfare encounters. As will be shown, such a CTP is built and maintained within the shipboard C3I system, where C3I is the term used to describe the information management infrastructure and processes employed by military organizations. With a CTP, the members of the command team (commanding officer, tactical action officer, etc.) hopefully have a better chance of making correct tactical decisions. Much more difficult to define are explicit requirements for the amount, quality, and type of data, as well as the type and source of processing used to form a CTP.

There are a multitude of sensors, sensor suites, and systems on the surface platforms of today, many employing increasingly flexible modes of operation, and all capable of independently providing huge amounts of sensor **data**. We indeed find ourselves, in most cases, in a "data-rich/ information-poor" environment where the amount and complexity of the sensor data is continuously increasing. It is important to establish a process for automatically assimilating this data into **information** that can be used by the command team to help them make correct tactical decisions. It is equally important to establish a methodology to efficiently assess, allocate, task, and control the sensors (and weapons) being used.

The U.S. Department of Defense in the past several years has expanded C3I to include computers (C4I), and surveillance and reconnaissance (C4ISR). This is meant to include information from inorganic real-time, near real-time, and time-latent ISR assets that may contribute to situation awareness and the "fused" CTP presented to the command team.

THE FEDERATED COMBAT SYSTEM (FCS)

The shipboard combat system is itself a C3I system, with the *combat control system* (CCS) acting as the control "backbone" of the combat system's C3I process. Likewise, the major subsystems associated with a ship's combat system can themselves be treated as C3I systems, e.g., a ship's electronic warfare system (EWS) and primary hard-kill system (HKS). Each major subsystem needs to manage and control the data and information generated by its respective sensors. In this approach, the major subsystems within the combat system are considered as federated elements, with each federated element employing its own command and control (C2) system and process. Such an FCS allows autonomous operation by each element, if and as necessary, while retaining overall C2 of the federated elements at the platform/ command CCS level. It is the control/management, assimilation, and integration of this sensor-generated data and information that poses the most difficult problem for humans and machines, at both the subsystem and combat-system levels.

The C3I architecture employed is also critical to the successful implementation of the C3I process and the building and maintaining of a CTP.

Combat control system (CCS) is a generic term. The U.S. Navy's (USN's) general term is combat direction system (CDS). USN CCS's include the Naval Tactical Data System (NTDS), Aegis Command and Decision (C&D), and Advanced CDS (ACDS).

THE COHERENT TACTICAL PICTURE

The *CTP* can be defined as a clear, consistent, and intuitively obvious display of all RWOs of interest to users **across the force**, within an operator-selectable region of interest. This includes vehicular and nonvehicular tracks, as well as geographic and political regions, and operating areas. Characteristics of the CTP include the following:

- One—and only one—continuous representation of every RWO of interest within range of sensor units in the theater
- Agreement among those units on the identifier and ID of the RWO
- Operator-selectable levels of display detail depending on specific needs

IDENTIFYING AND TRACKING RWOS

Surveillance consists of searching for, detecting, identifying, and tracking RWOs. The shipboard surveillance function is one of the major sources of data and information to be managed by a ship's C3I system. A variety of sensors and techniques are used to detect and identify these RWOs including:

- Radar
- Sonar

- Electronic Warfare Support (ES) detection
- Identification Friend or Foe/Selective Identification Feature (IFF/SIF) codes
- Observation of movement and activity
- Comparison with known flight paths
- Visual inspection

Identity is defined as a supplementary statement attributed to any track and consists of three elements:

- Hostility
- Platform type (which implies environment)
- Platform activity

ID plays a major role in achieving the capability to build and maintain a CTP.

Standard Identity is defined by NATO Standard Agreement 1241 as *Hostile*, *Suspect*, *Unknown*, *Neutral*, *Assumed Friend*, or *Friend*. A seventh term, *Pending*, is used until an identity is declared.

Tracking is the process of obtaining and plotting successive detections of an object to determine its course, speed, etc.—that is, the RWOs kinematics. ID and the kinematics of an RWO are critically important to building a CTP. The requirements for and amounts of other data and information needed for a CTP and by the command team are less clear.

COMMAND TEAM INFORMATION NEEDS

The command team is the overall tactical decision maker. The command team's ability to make correct tactical decisions is dependent on the correctness, completeness, timeliness, and quality of the information it receives. The primary source of this information is sensor-generated data, which is processed, managed, and presented for display. Each major combat-system subsystem uses a C3I process to manage this data and information. The initial processing of data at the subsystem level is performed by that subsystem's sensor or sensor/weapon system. This initial processing may include some form of data/information fusing, i.e., combining the sensor data/information into one representational format.

However this fused data/information is presented, the primary data and information needs of the command team are the *ID* and *kinematics* of the RWO. As will be shown later in this article, ID of the RWO allows an assessment of the RWO to begin, including threat evaluation (the "TE" of TEWA). Given a confidence level in this identification, this assessment may also include a request for additional data/information, either from previously used sensors, additional sensors, or possibly databases. If the RWO is identified as hostile, a resource allocation process then begins, including weapons assignment (the "WA" of TEWA).

The kinematics of the RWO are needed for a number of reasons, primarily for target tracking and fire-control solutions, the latter calculated once the RWO is identified as hostile. In some cases, the kinematics can also be used to aid in determining the intent of the RWO. The kinematics of an RWO include *position* and *velocity*, with position normally given using *azimuth*, *elevation*, and *range*.

It is the combination of the command team's need for the ID and kinematics of an RWO, the number and complexity of the sensor and data sources available, and the number and density of possible RWOs within a littoral environment that makes the building of a CTP so difficult and the command-level C3I process so complex. The information needed by the command team is clear—ID and kinematics. Less clear is the processing of this data into information, the integrating and cueing of the disparate sensors available, and the presenting of the resulting combined/integrated/fused data and information into a representational format that the command team can use to make decisions.

THE CTP AND TACTICAL DECISIONS

The purpose of compiling a CTP is not to produce a perfect tactical picture. The purpose is to produce a suitably accurate (and "coherent") tactical picture that allows confident tactical decisions to be made. At one extreme, a perfect CTP may enable a very effective tactical decision-making process to occur. However, the cost of compiling a perfect CTP may be too great and impractical.

A continuous stream of constantly changing sensor/source-generated data and information currently feeds the tactical picture. The tactical picture is also fed by intelligence information and background encyclopedic information and operational plans—termed **contextual information**—since it sets the context for the more dynamic real-time sensor/source information. Additional sensors, sensor systems, techniques, or assets can be explicitly tasked by the command team to gather more information, normally on a reactive basis. Currently, however, there is no concept of machine-assisted tasking to proactively gather more information—e.g., automatic sensor/information cueing—nor a concept to allow machines more autonomy.

The tactical decision may be a totally human decision, with or without machine-assisted decision aids. However, the more complex the tactical picture presented, the more the tactical decision may involve the use of knowledge-based decision aids. This might include complex decisions based on rules of engagement (ROE), orders of battle, expected threat levels, assets available, and/or operational constraints on own unit or own force. This may also include a "reflex" action, i.e., an action performed automatically when conditions (e.g., the threat, environment, battle situation, etc.) preclude a protracted decision-making process.

MULTISENSOR INTEGRATION (MSI)

In many of the major surface navies throughout the world, interest has grown in integrating stand-alone sensors into multisensor systems and fusing (combining) the data from these sensors. *MSI* refers to the synergistic use of multiple sensors to assist in the accomplishment of a task by a system. For example, multifunction radars (MFRs)—e.g., electronically scanned phased-array radars—have been built to perform both surveillance and tracking functions.

MSI can also mean the integration of dissimilar sensors, e.g., passive sensor systems (such as infrared (IR), electro-optic (EO), and ES sensors) and active sensor systems (such as radar). For example, a shipborne IR search and track (IRST) system might be integrated with a surveillance/tracking radar or MFR system.

SENSOR DATA FUSION

Compiling the CTP depends heavily on sensor *data fusion*; i.e., the process of combining sensor data and information into one representational format. MSI deals with such issues as the choice of sensors to accomplish a given task, type of system architecture to be employed (e.g., central versus distributed or federated processors), and communications. *Multisensor data fusion* (MSDF) refers to any stage of the MSI process in which data from multiple sensors is combined into one representational format. In contrast to MSI, MSDF deals with issues such as obtaining mathematical models of the various sensors in the system, and the choice or design of algorithms to actually combine the sensor data. The real challenge is developing sensor resource allocation algorithms that enable a multisensor system to select the appropriate sensing strategies. And the challenge is twofold: a preselection process, as well as a real-time selection process.

Similar-Sensor Integration/Fusion (SSI)

SSI is MSI using similar types of sensors. *Similar-sensor data fusion* (SSDF) is the association/correlation of tracks/contacts from the same type of sensor, i.e., MSDF of similar sensors. For example, two tracking radars can be integrated into a single system.

Dissimilar-Sensor Integration/Fusion

Dissimilar-sensor integration is MSI using multiple types of dissimilar sensors or sensor systems, normally with high-quality position and kinematics data. *Dissimilar-sensor data fusion* (DSDF) is the association/correlation of tracks/contacts from dissimilar types of sensors, i.e., MSDF of dissimilar sensors. Examples include sonar-to-radar correlation, IFF-to-radar correlation, ES-to-radar correlation, local-to-local/local-to-remote correlation, etc. DSDF is what is normally thought of when the term "sensor data fusion" is mentioned. The output is a composite track file normally with a combat system track number (TN). A source and source-identifier TN is also employed.

THE HUMAN'S ROLE IN SENSOR PROCESSING AND INTEGRATION

Given the early stage of development of MSI, MSDF, and machine-dominated decision-support systems, the human continues to play a major role in data processing, data interpretation, and decision-making. The consequences of incorrect "automatic" IDs and responses during regional operations within a semihostile littoral environment only reemphasizes the dilemma facing the designers of the combat systems of the future. On the one hand, the increased sophistication and capabilities of both the future threats and sensor systems equate to a more complex and data-intensive C3I process and resultant CTP, requiring increasing amounts of machine/computer assistance. On the other hand, a continued human-in-the-loop strategy, at various processing and interpretation stages of the C3I and CTP process, will remain as a safeguard to an "incorrect" automatic detection and response.

However, as the complexity of the situation increases, it becomes more and more difficult for one person to understand the complete tactical picture, and the need for a machine-assisted CTP and machine-assisted decision aids eventually becomes a necessity.

SENSOR CUEING

Current-generation antiship cruise missiles (ASCMs) will most probably be replaced (circa 2010) with ASCMs that will be faster, stealthier, lower flying, and more agile in the terminal phase. Faster ASCMs mean detection ranges must be increased to allow an adequate timeline for threat assessment, allocation of resources, and response, regardless of the environment. The combination of increased stealth and lower flying ASCMs makes radar detection more difficult, and introduces problems with multipath. Littoral operations mean:

- A cluttered air, land, and surface environment
- Large numbers of unidentified or neutral contacts
- Localized anomalous propagation effects

All of these add to the detection, ID, and tracking problem. Because a more proactive approach to information gathering is needed, the concept of sensor cueing has emerged.

Cueing is any action used as a signal to begin another action or operation. In ship-defense terms, *sensor cueing* is nominally any action that improves the capabilities of a ship's individual sensors, sensor systems, multisensor suite(s), or weapons and countermeasures systems to derive better quality, higher accuracy, or more valuable information or data than might otherwise be achievable in an equivalent stand-alone mode of operation. A sensor cue is basically stimulated by additional requirements for information in order for tactical decisions to be made.

Sensor cueing is normally used to enhance the detection range of potential targets that may otherwise be undetectable by a ship's primary active sensor due to the target's reduced radar signature and/or low altitude. In this case, passive sensors (e.g., IR, EO, and ES) can be used to cue an active sensor (e.g., radar). Sensor cueing can also be characterized as tasking for the purpose of gathering additional information/data. This includes being able to decide whether a contact should or should not be engaged. Sensor cueing is not solely threat driven; however, the need to gain information on a threat is by far the primary requirement for sensor cueing.

Alternatively, a sensor cue may arise from the need to deny information to the enemy. This may lead to a loss of information for tactical decision-making. However, the total benefit may be ownship concealment or, ultimately, survival. Emission control (EMCON) is an example of such a sensor cue.

The possibilities for acronyms are endless; e.g., Detect-Evaluate-Allocate-Respond = DEAR; Sense-Evaluate-Allocate-Respond = SEAR. However, Detect projects the image of finality (versus Sense), and Assess "fits" better as a descriptor since this action is actually *Situation Assessment*. Likewise, Allocation is the initial stages of *Resource Allocation*. More important than the acronym are the sequence of actions and the overall C2 of the sequence, whatever the system or subsystem being described.

TACTICAL DECISION-MAKING

MSI and sensor cueing strategies are a part of the C3I process. To begin the process of developing a better understanding of the C3I process, compiling the CTP, sensor tasking and cueing, and the algorithms necessary to control the C3I process, a basic C3I model is needed. This will provide those involved in the design of shipboard C3I systems a common framework and focus for the C3I process.

There are many models to describe the decision-making process. A model for human decision-making has been previously used by Wohl[1] in tactical air defense systems and designated the Stimulus, Hypothesis, Options, and Response (SHORE) paradigm. Various organizations have adapted this paradigm to describe the C3I process, either purposely or inadvertently. The Naval Surface Warfare Center, Dahlgren Division (NSWCDD) has for years used a similar paradigm, describing the engagement scenario decision timeline as a Detect, Control, and Engage sequence. (More recently this has become Plan, Sense, Control, and Act.) This description, however, is somewhat confusing and limited given the need for the Control element in both the Detect/Sense and Engage/Act stages.

A much more understandable and intuitively satisfying approach is illustrated in Figure 1. Here, the SHORE paradigm has been modified into a Detect, Assess, Allocate, and Respond (DAARE) sequence. The DAARE sequence can be briefly summarized as follows.

THE DAARE SEQUENCE: DETECT, ASSESS, ALLOCATE, AND RESPOND

The sequence is initiated by sensor *detection* of a RWO. The resultant data (whatever its source) is prioritized and initially processed. Next, an *assessment* is made, which will include data fusion, situation assessment, ID, and threat evaluation. This may be first-level or all-source data fusion (described later), depending on the system being described. The CTP is part of situation assessment. At this point, additional data may be required to assist in the assessment, thereby requiring additional (cued) sensor assets. Next, *allocation* of resources begins, which includes weapons systems coordination (WSC) and weapons assignment. The final stage of the sequence is a *response*. This can, once again, include a request for additional sensor assets, as well as a weapons engagement response. An *assessment* of the *response* (one assessment being a "kill" assessment) completes the C3I process. The response assessment may conclude that previous data or information needs to be reassessed. Likewise, a response assessment might include the cueing of additional sensors and/or information sources, followed once again by assessment, allocation, etc. Central to this sequence is the C2 function, particularly Control, which forms the backbone of the C3I process.

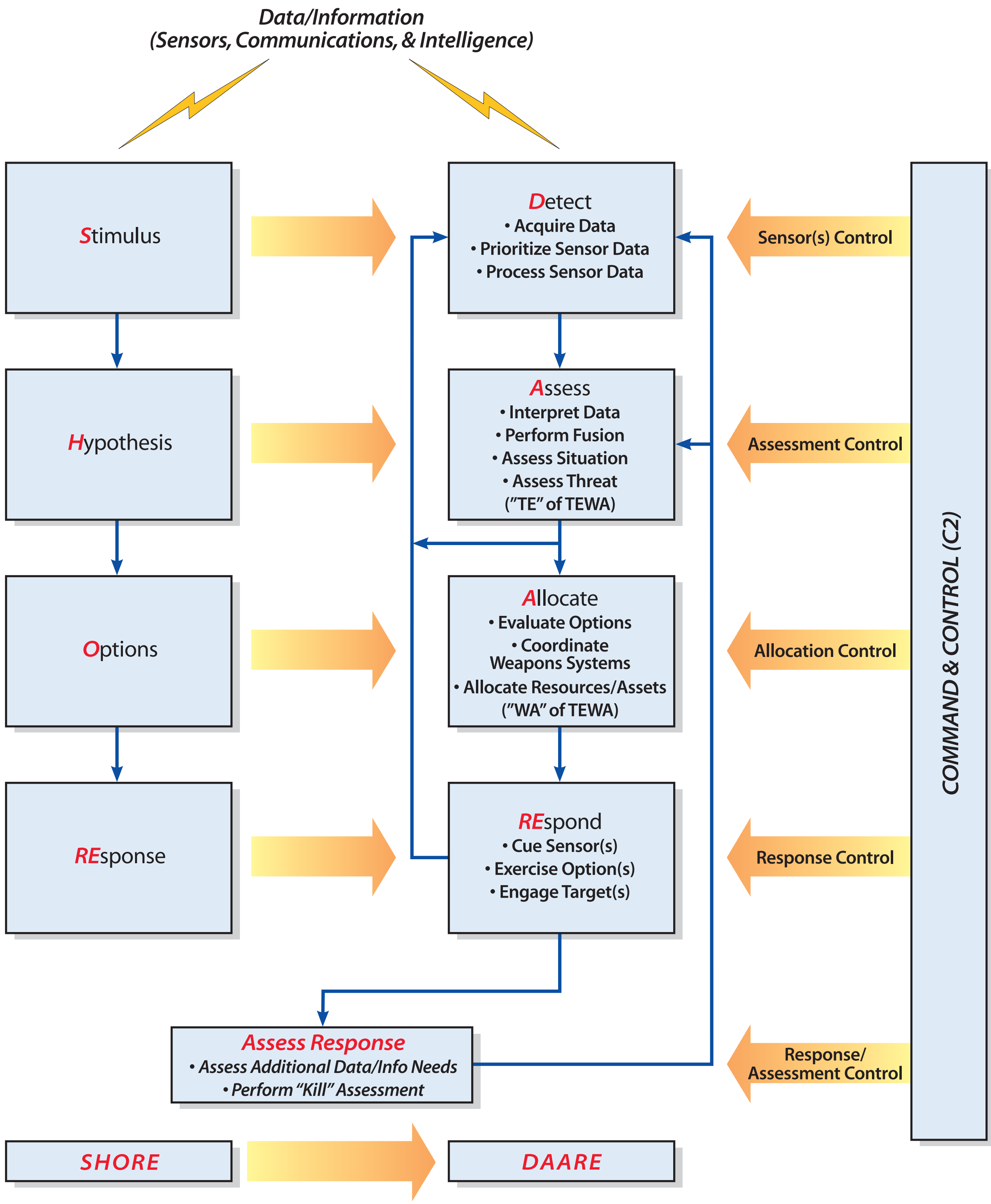

Figure 1—The SHORE Paradigm Modified to the DAARE Sequence

The DAARE sequence can be applied to any C3I system, including the combat system and/or any of the federated subsystems within the Combat System (e.g., the EWS). Similarly, the C2 function can be applied to the combat system (i.e., CCS) or any of its federated subsystems (e.g., EWC2). This "Control" function and the architecture that follows should also be applicable to force- and theater-level C2, i.e., a force/theater-level equivalent to a shipboard CCS.

A further question to ponder, but beyond the scope of this article: How do such systems interact to form larger C3I systems? *Policy* may be the interaction link, allowing lower C3I systems to perform autonomously, versus direct-command control. This is also consistent with the philosophy of federated subsystems.

APPLYING DAARE TO THE C3I PROCESS

Given the SHORE-to-DAARE adaptation, it remains to apply specifics to the DAARE sequence to fully describe the C3I process, including the use of sensor cueing. An FCS has been assumed in the following discussions. This means a platform-level C2 process has likewise been assumed. Figure 2 illustrates the specific application of the DAARE sequence to the C3I process. The following paragraphs step through the C3I process shown in Figure 2.

Detect: Sensing the RWO and Initial Data Processing

The stimulus that begins the C3I process is the detection of an RWO. This initiates the flow of data and information that must be assessed and fused to form a CTP for the decision makers.

Data/Information Sources and Acquisition

The first step in forming a CTP is detecting, locating, tracking, and if possible, classifying all RWOs that might contribute to the tactical situation. Sources of data and information can include the following broad categories:

Sensors—Data and information are normally acquired in real time via ownship onboard sensors or sensor systems. These include:

- Radars (including short- and long-range, navigational, surveillance, and tracking)
- IFF/SIF
- ES
- Active and passive sonar (including towed arrays)
- IR
- EO

An additional "sensor" is the human, using his sight or hearing, either with or without machine assistance. Individual sensors (S1, S2, etc.) detect the RWO, initially process the data (P1, P2, etc.), and perform first-level fusion on the data (F1, F2, etc.).

Communications/Tactical Data Links (TDLs)—Other ships within the force may also detect the RWO, and likewise perform the same "ownship" process just described. This first-level fused data is distributed among the force via communications links, including *TDLs*, such as Link-11 and Link-16. This data and information may or may not be time delayed.

Intelligence—The final source of data and information is intelligence reports. This includes electronic (ELINT), communications (COMINT), and human (HUMINT) intelligence. This source is almost always time delayed.

There is other information and data available, including planning and command information, equipment databases, and mission data. This can be termed *command support information* (CSI). Likewise, environmental, encyclopedic, and geographic data may be available, including commercial air lanes, static seabed objects (e.g., wrecks), etc. This is considered contextual

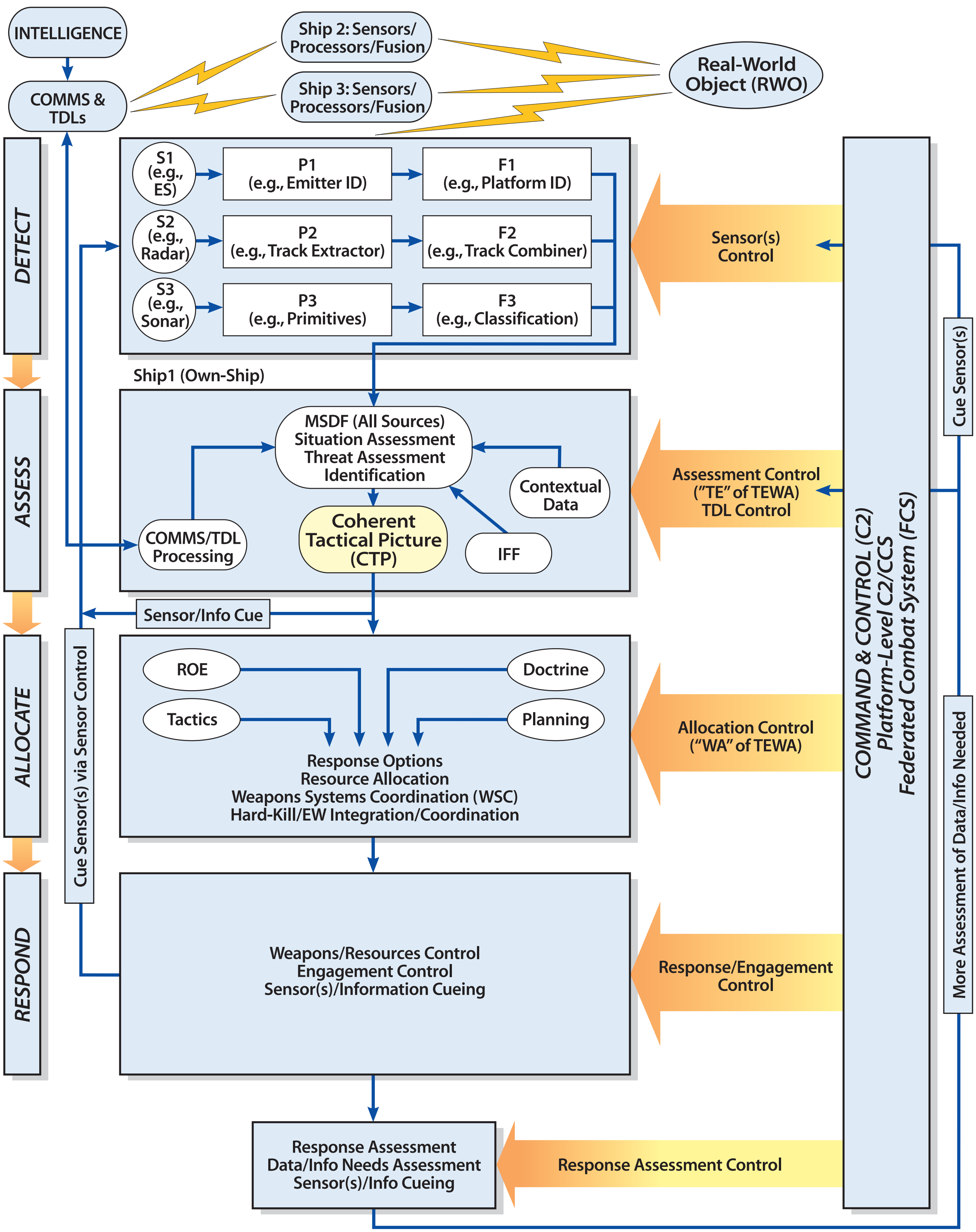

Figure 2—DAARE Applied to the C3I Process

information since it sets the context for the more dynamic real-time sensor/source information.

Data/Information Prioritization: Weighting the Data/Information Sources

While a human may have a cognitive ability to prioritize data and information that is presented to him, it is much more difficult to enable a machine to do this. Even a human can become overwhelmed with information, particularly when faced with many sources, mixed real-time and time-latent information, and stressful tactical situations.

A first step in dealing with the many disparate sources of data and information is to prioritize the data coming in by weighting the importance of the data source. This might be as simple as giving more weight (importance) to real-time versus time-latent data sources. It might also include a hierarchy of source importance—e.g., radar, ES, IR, EO, TDL, etc.—from most important to least important.

Initial Sensor Data Processing

The Detect phase of the C3I process includes the initial processing performed by each individual federated sensor, sensor suite, or sensor system. It also includes SSDF. This initial processing, and what can be called "first-order" data fusion from similar sensors/sources, is controlled initially by the individual sensor system's C2. Therefore, within the ship's combat system, each federated subsystem (e.g., the EWS) performs initial processing and first-order fusion on the data (e.g., emitter signal parameters) detected by its sensor (e.g., ES) system. In this example, control of this process is via EWC2. The reasoning is simple—detection, initial processing, first-order fusion, and process control of this data should be performed by the system specifically designed and equipped to perform this function.

Sensor-tasking (and cueing) algorithms are also needed that enable a multisensor system to select the appropriate sensing strategies. Look-up-table sensor ploys may be able to be developed as part of a preselection process. However, the tasking and cueing of sensors throughout the C3I process requires a real-time selection process to deal with the changing dynamics of an at-sea environment. This most likely will require the development of knowledge-based sensor cues, with algorithms capable of dealing with dynamic situations.

Assess: Situation Assessment, Threat Evaluation, ID, and the CTP

The next step in the C3I process illustrated in Figure 2 is a Hypothesis for the Stimuli that has occurred. In a tactical situation this equates to assessing the situation; i.e., *Situation Assessment*. This is a combat-system- (i.e., CCS) level function. This means taking all the first-order fused data/information available from the many disparate stimuli (sensors) of the Detect phase and fusing this data into a CTP. This MSDF process (sometimes called *All-Source Fusion*) also includes threat evaluation. Other sources of information used during this phase by the CCS are IFF, intelligence, and TDLs.

Multisensor Data Fusion: Confidence Levels

In order for the MSDF and assessment process to be successful, some form of confidence level needs to be assigned to the data/information arriving from the Detect phase. This is especially true of the emitter-to-platform correlations and IDs sent by the EWS's ES system. This is vitally important regardless of the data/information assessor, i.e., human or machine.

Situation and Threat Assessment/Evaluation

The combination of weighted (for importance) sensors/sources and confidence levels for the data/information arriving from each respective sensor source should allow some form of machine-assisted situation assessment to begin. At this point, contextual information, communications and TDL-processed data, and IFF data are brought into the MSDF process.

Command-level threat evaluation is also performed at this time, the first step in the command-level TEWA process.

Identification

The final, and most important, step in the Assess phase is ID of the RWO. Depending on that ID, the allocation of assets/weapons may or may not proceed. Indeed, the sensor/source data/information may be of such poor quality that an assessment of the ID of the RWO cannot be made. This may result in additional information being needed, requiring the cueing of additional or previously employed sensor(s).

Allocate: Resource Allocation, Weapons Assignment, and WSC

The third step in the C3I process is determining and deciding on Options. In the DAARE C3I process, this has been designated Allocate, i.e., *Resource Allocation*. It is during this phase that use of CSI is made, e.g., plans, tactics, doctrine, ROE, etc., established during earlier CSI-related planning. This information is incorporated into the process used in determining how and what resources to allocate. It sets constraints on the allocation of resources and can modify or veto resource plans (prior to the use of a resource). This includes the second stage of TEWA; i.e., weapons assignment. It is also a logical point to incorporate a WSC scheme.

Evaluation of Options

For the most adaptability in the dynamic environments normally associated with littoral combat situations, a knowledge-based approach to the evaluation of options and resource allocation seems most appropriate. A first step may be a library-based look-up table.

Weapons Assignment and Weapons Systems Coordination

Weapons coordination, integration, and assignment should be a command-level (CCS) function. However, individual weapons systems should have an autonomous weapons assignment option, with command concurrence (or because of command inaccessibility) to operate in an "autonomous" independent mode. For example, the EWS may employ a *Reflex* mode for the Electronic Attack (EA) system that automatically responds to a threat alert with the appropriate EA technique. A similar EWS Reflex mode may be used to cue an HKS's primary radar in response to a specific ES detection.

WSC is also accomplished in this phase. Again, because of the dynamic littoral battle environment, knowledge-based weapons ploys seem much more appropriate.

Hard-Kill and EW Coordination

This command/CCS-level function integrates hard-kill resources (e.g., missiles) and EW resources (e.g., onboard and offboard EA systems), allowing coordinated and cooperative responses to hostile RWOs. This function also includes EMCON.

RESPOND: SENSOR CUEING AND ENGAGEMENT

The final phase in the C3I process is Response. This might mean a hard-kill response, EA response, a coordinated response employing a combination of resources or assets, or a decision to cue additional sensors or data/information sources.

Weapons/Resources and Engagement Control

Overall integration and control of weapons and resources should also be at the command (CCS) level. As with weapons assignment and WSC, provisions should be incorporated for autonomous weapons control by individual federated systems, with command-level concurrence. Likewise, control and coordination of the engagement(s) is a command-level function.

Sensor/Information Cueing: Data and Information Update

Within the DAARE sequence, Respond can also mean a request (or cue) for additional data/information, including:

- The cueing of a sensor or several sensors
- The cueing of data/information sources or several sources
- The cueing of a combination of sensors and other data/information sources

Assess Response: Kill Assessment

As in the human decision-making process, any response needs to be assessed to determine the result of the response. In tactical terms, this may require additional data/information from sensors or other data sources.

Assessment of Additional Data/Information Needs

Depending on the initial response, the assessment may be that additional data or information is needed. This may include bringing to bear additional sensors or sensors previously used. It may also mean the need to reassess information or data available from communications or TDL processing, CSI, contextual data, or the MSDF process. Sensors are cued via sensor control (see *Cue Sensor(s)* on RHS of Figure 2); other data/information currently or previously available is reassessed via assessment control.

Assessment of Response ("Kill" Assessment)

By far the most commonly associated tactical response assessment is kill assessment, i.e., has the hostile targeted RWO been destroyed or rendered harmless or ineffective. This assessment will almost certainly employ appropriate sensors that can be brought to bear on the RWO. In this case, the appropriate sensors are cued via sensor control, with coordination at the command level. The assess/allocate/respond sequence is then repeated.

COMMAND AND CONTROL (C2): THE C3I "CONTROL BACKBONE"

Whether at the federated subsystem levels of the combat system, the combat-system level, the platform level, or the force level, C2 is the control backbone of any C3I system. The C2 system must control the overall C3I process, namely detection, assessment, allocation, response, and response (kill) assessment. At the combat-system level this is the CCS. This is the command team's link between the combat system and the combat system's federated subsystems—the platform-level control essential to managing the data and resources available to the command team.

At the force level, this may be the CCS of a designated "Force Command" platform, such as a CVN. The task of the Force Command's CCS would be the same as an individual ship's CCS; i.e., provide a forcewide CTP, and coordinate and allocate resources.

SUMMARY

A CTP is paramount to a naval force's ability to conduct operations in the littoral environment of today's surface warfare encounters. The CTP is built and maintained within the shipboard C3I system. While not a "perfect" representation of the tactical picture, a CTP should help the command team to make more informed tactical decisions.

The primary shipboard C3I system is the combat system, with the command team the overall tactical decision maker and the CCS the Control "backbone" of the combat system's C3I process. The FCS architectures envisioned have major subsystems that are themselves federated C3I systems, e.g., the EWS. Each primary subsystem manages and controls the information generated by its respective sensors, employing both humans and machines (i.e., computers) to aid in each subsystem's C3I process.

In order to provide those involved in the design of C3I systems (e.g., FCS's) with a common framework and focus for the C3I process, a basic C3I model is needed. To this end, the author has redefined the SHORE paradigm to illustrate the overall C3I process. The SHORE paradigm applies a Stimulus-Hypothesis-Options-Response sequence to the tactical decision-making process. The redefined sequence to describe the C3I process is a DAARE sequence. Using a Control "Backbone," the DAARE sequence forms a logical functional framework for describing the shipboard C3I process. Though not shown in this article, the DAARE sequence can also be applied to the task of partitioning the functions and describing the data flow among the three principal subsystems of an FCS, namely the CCS, EWS, and primary HKS. It may also offer a basis for the definition of a "common" CDS, as well as a framework for the allocation of functions within the common CDS and among its associated combat-system subsystems. Still to be determined is the applicability of a functional framework such as DAARE to force- and theater-level C3I issues.

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THE AUTHOR

MR. LAWRENCE H. LUESSEN

Mr. Lawrence H. Luessen is a Systems Engineer in the Maritime Defense Division of the Theater Warfare Systems Department. He has a B.A. degree in physics from Gettysburg College and an M.S.E.E. from Duke University. The author has been program manager for the Navy's Special Effects Warhead and Pulsed Power Technology programs, and has served as Branch Head for the Directed Energy Branch, Pulsed Power Systems and Technology Branch, and Electronic Warfare Systems Engineering Branch at NSWCDD. He has also spent a year in the Office of Chief of Naval Operations working in the Technology Assessment Division. Mr. Luessen recently returned from a 2-year Navy International Programs Office-sponsored assignment at the Defence Evaluation and Research Agency (DERA), Portsdown West, Hampshire, United Kingdom. His time at DERA was spent investigating combat system integration, sensor data fusion, and tactical picture compilation issues. He is currently NSWCDD's Cooperative Engagement Capability (CEC) Program Manager.